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INVENTORS: Braulio A. POLANCO
Christopher Dale FENWICK
Darryl Franklin CLARK
Bryan David HAYNES
Kurtis Lee BROWN
Chad Michael FREESE
Eric Scott KEPNER

TITLE: HIGH LOFT LOW DENSITY NONWOVEN WEBS OF CRIMPED FILAMENTS AND METHODS OF MAKING SAME

ATTORNEY: Roland W. Norris, Esq.
Pauley Petersen & Erickson
2800 West Higgins Road
Suite 365
Hoffman Estates, Illinois 60195
(847) 490-1400

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HIGH LOFT LOW DENSITY NONWOVEN WEBS OF CRIMPED FILAMENTS AND METHODS OF MAKING SAME

This application is a Continuation In Part application and claims priority from U.S. Application serial no. 10/037,467, filed 21 December 2001.

BACKGROUND OF THE INVENTION

This invention relates to a high loft, low density nonwoven material produced from continuous fibers in which the lofty character of the nonwoven material is the result of the fibers comprising the web having a Z-direction orientation, resulting from improved processing and the resultant crimping. These materials have increased uniformity and are particularly suitable for use in a broad range of applications including, without limitation, surge layers for personal care products, acoustic and thermal insulation, packing material, padding, absorbents, filtering, and cleaning materials.

DISCUSSION OF THE RELATED ART

In nonwoven webs, the fibers comprising the web are generally oriented in the X-Y plane of the web and the resulting nonwoven web material is relatively thin, that is, lacking in loft or significant thickness.

Loft or thickness in a nonwoven web suitable for use in personal care absorbent articles promotes comfort (softness) to the user, surge management and fluid distribution to adjacent layers. In order to impart loft or thickness to a nonwoven web, it is generally desirable that at least a portion of the fibers comprising the web be oriented in the z-direction. Conventionally, lofty nonwoven webs are produced using staple fibers. See, for example, U.S. Patent 4,837,067 which teaches a nonwoven thermal insulating batt comprising structural staple fibers and bonding staple fibers which are entangled and substantially parallel to the faces of the batt at the face portions and substantially perpendicular to the faces of the batt, and U.S. Patent 4,590,114 which teaches a batt including a major percent of thermo-mechanical wood pulp fibers stabilized by the inclusion of a minor percent of thermoplastic fibers including staple length thermoplastic fibers. Alternatively, conventional high loft forming processes rely on pre-forming processes such as fiber crimp formed on a flat wire or drum, and post-forming processes such as creping or pleating of the formed web.

Others in the art have sought to provide lofty materials by first forming a standard nonwoven web, and then pleating or corrugating that web by folding the web upon itself. However, in such constructions the fibers of the web still remain in the plane of the web, it is only the plane of the web itself which has been distorted.

Inventions related hereto by the fact that the fibers have true z-direction orientation outside of the plane of the web, such as U.S. Patent No. 6,588,080 may generally be characterized as forming a lofty material which has folds induced in the base material fibers, producing Z-direction fibers through the use of a transfer process between differential speed forming wires.

However, there exists a need in the art for alternative high loft, low density fabrics which may exhibit a good balance of fluid control having fast intake, low flow back and high horizontal distribution, as well as good web morphology, and the other above-mentioned properties including insulation, padding, and the like.

SUMMARY OF THE INVENTION

In response to the above-described needs in the art, the present invention utilizes the natural crimping ability of certain bicomponent, substantially continuous, thermoplastic fibers of A/B configuration, i.e., generally side by side or eccentric sheath/core, construction to produce high loft, low density nonwoven webs of increased uniformity over comparable fabrics of the known art. While this class of fiber types is known in the art, per se, special processing parameters are applied by the present invention to derive precursor filaments suitable for processing into high loft, low density fabrics. The fibers are then crimped into high loft, low density fabrics by novel techniques applied after filament formation. Additionally, new techniques were developed to ensure the stability of the resultant high loft, low density fabrics after the filaments have been crimped.

In one aspect of the invention, the new fabrics may comprise a high loft, low density nonwoven web having a web of substantially continuous, spunbond, helically crimped, bicomponent fibers of A/B side by side morphology. Within the web the fibers are randomly crimped to produce a lofted material with heterogeneous, random, fiber orientation, including heterogeneous z-direction orientation to produce loft, bulk or thickness of the web, and irregularly spaced openings between the crimped fibers. By way of illustration lofty webs of the present invention may have a basis weight from about 0.3 osy to 25 osy exhibiting densities

from about 0.002g/cc to 0.05g/cc and lofts from 0.02" (inches) to 1.5". For example, a 0.5 osy web may exhibit loft from about 0.03" to 0.3" at a density range of 0.022 to 0.002g/cc. As another example, a 3.0 osy web may exhibit loft from 0.1" to 1.5" at a density range of 0.04 to 0.003g/cc.

Uniformity of the webs of the present invention may be measured by a formation index value derived from a commercially available MK Formation Analyzer model 960, from MK Systems Inc. of Danvers, Massachusetts, as set forth in greater detail below. A nonwoven material according to certain aspects of the present invention may comprise a web of substantially continuous A/B bicomponent crimped fibers with the web having a percentage difference between a formation index of a top side of the web, i.e., the major plane surface of the web not in contact with the forming surface, also called a forming wire, and a formation index of a wire side of the web, i.e., the major plane surface of the web which is in contact with the forming wire, of less than about 11%.

Improvements in formation (or sheet uniformity), as measured by formation index values, have been known to improve fabric strength and thus the performance of the fabric in its conversion or incorporation into absorbent articles. Formation index values, however, being based on light transmission/reflectance of the webs, should not be used as a comparison between different grades of nonwoven webs, e.g., different colors, basis weights, TiO_2 contents, or the like; which may affect light transmission/reflectance of the webs. Therefore, in characterizing the present invention care must be taken and overall ranges and values of the formation index values may be stated in the alternative and related closely to the morphological characteristics and the surface of the nonwoven web that is being measured.

For example, in some aspects of the present invention, the nonwoven materials may have a formation index averaging above about 37.6 on the top side of the web when the web has a bulk to about 0.1 inches in the Z axis, or a formation index averaging above about 32.03 on the top side of the web when the web has a bulk of over about 0.1 inches in the Z axis. In other aspects of the present invention the nonwoven materials may have a formation index averaging above about 43.76 on the wire side of the web when the web has a bulk to about 0.1 inches in the Z axis or a formation index averaging above about 37.09 on the wire side of the web when the web has a bulk of over about 0.1 inches in the Z axis.

In some aspects of the present invention, the nonwoven materials may have a

formation index averaging above about 37.6 on the top side of the web when the web has a basis weight of up to 1.5 osy, or a formation index averaging above about 32.03 on the top side of the web when the web has a basis weight of over about 1.5 osy. In other aspects of the present invention, the nonwoven materials may have a formation index averaging above about 43.76 on the wire side of the web when the web has a basis weight of up to 1.5 osy, or a formation index averaging above about 37.09 on the wire side of the web when the web has a basis weight of over about 1.5 osy.

In some aspects of the present invention, the nonwoven materials may have a formation index averaging above about 19.07 on the top side of the web when the web has a bulk of about 0.35 inches in the Z axis, or a formation index averaging above about 32.03 on the top side of the web when the web has a bulk of about 0.12 inches in the Z axis, or a formation index averaging above about 28.73 on the top side of the web when the web has a bulk of about 0.1 inches in the Z axis, or a formation index averaging above about 34.63 on the top side of the web when the web has a bulk of about 0.08 inches in the Z axis, or a formation index averaging above about 37.6 on the top side of the web when the web has a bulk of about 0.07 inches in the Z axis.

In some aspects of the present invention, the nonwoven materials may have a formation index averaging above about 31.6 on the wire side of the web when the web has a bulk of about 0.35 inches in the Z axis, or a formation index averaging above about 37.09 on the wire side of the web when the web has a bulk of about 0.12 inches in the Z axis, or a formation index averaging above about 35.37 on the wire side of the web when the web has a bulk of about 0.1 inches in the Z axis, or a formation index averaging above about 38.98 on the wire side of the web when the web has a bulk of about 0.08 inches in the Z axis, or a formation index averaging above about 43.76 on the wire side of the web when the web has a bulk of about 0.07 inches in the Z axis.

In some aspects of the present invention, the nonwoven materials may have a formation index averaging above about 19.07 on the top side of a web having a basis weight of about 6.0 osy, or a formation index averaging above about 32.03 on the top side of a web having a basis weight of about 2.5 osy, or a formation index averaging above about 30.27 on the top side of a web having a basis weight of about 2.25 osy, or a formation index averaging above about 28.73 on the top side of a web having a basis weight of about 1.5 osy, or a

formation index averaging above about 31.07 on the top side of a web having a basis weight of about 1.2 osy, or a formation index averaging above about 34.63 on the top side of a web having has a basis weight of about 1.0 osy, or a formation index averaging above about 37.6 on the top side of a web having a basis weight of about 0.75 osy.

In some aspects of the present invention, the nonwoven materials may have a formation index averaging above about 31.6 on the wire side of a web which has a basis weight of about 6.0 osy, or a formation index averaging above about 35.03 on the wire side of a web which has a basis weight of about 2.25 osy, or a formation index averaging above about 37.09 on the wire side of a web which has a basis weight of about 2.5 osy, or a formation index averaging above about 35.37 on the wire side of a web which has a basis weight of about 1.5 osy, or a formation index averaging above about 37.15 on the wire side of a web which has a basis weight of about 1.2 osy, or a formation index averaging above about 38.98 on the wire side of a web which has a basis weight of about 1.0 osy, or a formation index averaging above about 43.76 on the wire side of a web which has a basis weight of about 0.75 osy.

In some aspects of the present invention, the nonwoven materials may have fibers having a fiber denier of between about 0.1 dpf to about 9.0 dpf, or between about 0.1 dpf to about 6.0 dpf, or between about 0.1 dpf to about 5.0 dpf, or between about 0.1 dpf to about 4.2 dpf or between about 0.1 dpf to about 3.3 dpf, or between about 3.4 dpf to about 4.2 dpf. The fibers may have a substantially white color which may include a TiO_2 percentage of about 0.1% to about 5% or a TiO_2 percentage of about 2%.

In some aspects of the present invention, the nonwoven materials may have the fibers of the nonwoven web integrally bonded. In some aspects of the present invention, the nonwoven materials may have a web of substantially continuous A/B bicomponent crimped fibers with the web having a formation index averaging above about 37.6 on the top side of the web when the web has a bulk to about 0.1 inches in the Z axis, or a formation index averaging above about 32.03 on the top side of the web when the web has a bulk of over about 0.1 inches in the Z axis.

In some aspects of the present invention, the nonwoven materials may have a web of substantially continuous A/B bicomponent crimped fibers with the web having a formation index averaging above about 43.76 on the wire side of the web when the web has a bulk to about 0.1 inches in the Z axis, or a formation index averaging above about 37.09 on

the wire side of the web when the web has a bulk of over about 0.1 inches in the Z axis.

In another aspect the new fabrics may comprise a high loft, low density nonwoven web made from highly machine direction oriented, substantially continuous, spunbond, helically crimped, bicomponent fibers of A/B side by side morphology. Within the web the fibers are randomly crimped to produce a lofted material with a very high loft by inducing shingled layers with a buckled Z-direction orientation to produce loft of the web, and irregularly spaced openings between the crimped fibers.

The methodology for making high loft, low density nonwoven webs according to the present invention may include initially producing the bicomponent filaments without heat before collection of the filaments, e.g., by using an unheated fiber draw unit (FDU) rather than using the heated FDUs prevalent in the art. The present invention is not limited to those fibers formed with an FDU. Other fiber forming apparatus, e.g., such as those described in U.S. Patents 4,692,106 to Grabowski et al. or 4,820,459 and 4,851,179, both to Reifenhauser, may be used, or those described in U.S. Patents 5,814,349; 5,766,646, and 5,571,537; all of which are incorporated by reference in their entirety. The fibers are then collected on the forming surface and heated to relax, i.e. relieve the forces restraining the inherent molecular orientation present in, the bicomponent fiber structure and initiate crimping. Immediately after this heating the web is cooled so that the fibers do not bond, thereby maintaining the mobility of the fibers and allowing the fibers to crimp to the desired extent. Other processing parameters such as wire vacuum may be controlled to further allow the fibers to crimp unimpeded. Upon crimping, a high loft, low density fabric is created. Additional heating is then applied to set the web. Processing parameters can be controlled in the final heating phase to maintain the web in the original high loft, low density state or the parameters may be controlled to adjust the density and loft of the web during this phase.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and features of this invention will be better understood from the following detailed description taken in conjunction with the drawings wherein:

Fig. 1 illustrates a process and apparatus for producing a lofty, nonwoven material in accordance with one embodiment of this invention;

Fig. 2 is a photograph of a side view, or cross section along the machine direction axis, of a high loft, low density nonwoven web having z-direction components as formed with low machine direction orientation and through air bonding;

Fig. 3 is a photograph of a side view, or cross section along the machine direction axis, of a high loft, low density nonwoven web having z-direction components as formed with low machine direction orientation and static air bonding;

Fig. 4 is a photograph of a side view, or cross section along the machine direction axis, of a high loft, low density nonwoven web having z-direction components as formed with high machine direction orientation and through air bonding;

Fig. 5 is a photograph of a side view, or cross section along the machine direction axis, of a high loft, low density nonwoven web having z-direction components as formed with high machine direction orientation and static air bonding;

Fig. 6 is a photograph of fibers produced from a known hot FDU exhibiting a typical tight crimp; and

Fig. 7 is a photograph of fibers produced from an ambient non-heated FDU exhibiting a relaxed crimp.

DEFINITIONS

As used herein, the term "nonwoven web" or "nonwoven material" means a web having a structure of individual fibers, filaments or threads which are interlaid, but not in a regular or identifiable manner such as those in a knitted fabric or films that have been fibrillated. Nonwoven webs or materials have been formed from many processes such as, for example, meltblowing processes, spunbonding processes, and bonded carded web processes. The basis weight of nonwoven webs or materials is usually expressed in ounces of material per square yard (osy) or grams per square meter (gsm), and the fiber diameters are usually expressed in microns. Another frequently used expression of fiber diameter is denier, which is defined as grams per 9000 meters of a fiber and may be calculated as fiber diameter in microns (μm) squared, multiplied by the polymer density in grams/cc, multiplied by 0.00707. A lower denier indicates a finer fiber and a higher denier indicates a thicker or heavier fiber. For example, the diameter of a polypropylene fiber given as 15 microns (μm) may be converted to denier by squaring, multiplying the result by 0.89 g/cc and multiplying by 0.00707. Thus, a 15 micron (μm) polypropylene fiber has a denier of about 1.42 (15^2 x 0.89 x .00707 = 1.415). Outside the

United States the unit of measurement is more commonly the "tex", which is defined as the grams per kilometer of fiber. Tex may be calculated as denier/9. (Note that to convert from osy to gsm, multiply osy by 33.91.)

As used herein, the term "Z-direction" refers to fibers disposed outside of the plane of orientation of a web. A web will be considered to have an x-axis in the machine direction, a y-axis in the cross machine direction and a Z-axis in the loft direction, with its major planes, or surfaces, lying parallel with the X-Y plane. The term "as formed Z-direction fibers" may be used herein to refer to fibers that become oriented in the z-direction during forming of the nonwoven web as distinguished from fibers having a Z-direction component resulting from post-forming processing of the nonwoven web, such as in the case of mechanically crimped or creped or otherwise disrupted nonwoven webs.

"Formation index" refers to the M/K test formation index value as set forth herein and is a measurement of uniformity of web formation. The index value is the quotient of the number of pixels in the modal (most common) weight class of pixel light divided by the total number of weight classes observed, divided by a factor of 100 for normalization. The higher the M/K formation index, the better the formation uniformity. A formation index value can vary dependent upon the surface of the web measured. Hence, "top side" and "bottom side," also sometimes called "wire side," refer to the two major surfaces of the web in the x-y plane and are denominated according to the proximity of the surfaces to the forming surface.

"Integrally bonded" as used herein refers to the bonding of a layer of material without adhering the subject web to additional webs.

"Low machine direction orientation" and "high machine direction orientation" as used herein refers to the degree to which the fibers of a nonwoven web are allowed to disperse over the cross direction of the forming surface, e.g. a foraminous wire. Low machine direction orientation fibers are dispersed across the cross direction to a higher degree than a collection of fibers exhibiting a higher machine direction orientation which have less dispersion over the cross direction of the forming surface during the formation of a web.

As used herein, the term "substantially continuous fibers" refers to fibers which are not cut from their original length prior to being formed into a nonwoven web or fabric. Substantially continuous fibers may have average lengths ranging from greater than about 15 centimeters to more than one meter, and up to the length of the web or fabric being formed.

The definition of "substantially continuous fibers" includes fibers which are not cut prior to being formed into a nonwoven web or fabric, but which are later cut when the nonwoven web or fabric is cut, and fibers which are substantially linear or crimped.

As used herein, the term "through-air bonding" or "TAB" refers to any process of integrally bonding a nonwoven by adhering the fibers of the web to each other, for example a bicomponent fiber web, in which air which is sufficiently hot to melt one of the polymers of which the fibers of the web are made is forced through the web.

As used herein "side by side fibers" belong to the class of bicomponent or conjugate fibers. The term "bicomponent fibers" refers to fibers which have been formed from at least two polymers extruded from separate extruders but spun together to form one fiber. Bicomponent fibers are also sometimes referred to as conjugate fibers or multicomponent fibers. Bicomponent fibers are taught, e.g., by U.S. Patent 5,382,400 to Pike et al. which is incorporated by reference in its entirety. The polymers of conjugate fibers are usually different from each other though some conjugate fibers may be monocomponent fibers. Conjugate fibers are taught in U.S. Patent 5,108,820 to Kaneko et al., U.S. Patent 4,795,668 to Krueger et al. and U.S. Patent 5,336,552 to Strack et al. all of which are incorporated by reference in their entirety. Conjugate fibers may be used to produce crimp in the fibers by using the differential rates of expansion and contraction of the two (or more) polymers.

Words of degree, such as "about", "substantially", and the like are used herein in the sense of "at, or nearly at, when given the manufacturing, design, material and testing tolerances inherent in the stated circumstances" and are used to prevent the unscrupulous infringer from unfairly taking advantage of the invention disclosure where exact or absolute figures are stated as an aid to understanding the invention.

As used herein, the term "machine direction" or MD means the length of a fabric in the direction in which it is produced. The term "cross machine direction" or CD means the width of fabric, i.e. a direction generally perpendicular to the MD.

"Particle," "particles," "particulate," "particulates" and the like, refer to a material that is generally in the form of discrete units. The particles can include granules, pulverulents, powders or spheres. Thus, the particles can have any desired shape such as, for example, cubic, rod-like, polyhedral, spherical or semi-spherical, rounded or semi-rounded, angular, irregular, etc. Shapes having a large greatest dimension/smallest dimension ratio, like

needles, flakes and fibers, are also contemplated for use herein. The use of "particle" or "particulate" may also describe an agglomeration including more than one particle, particulate or the like.

"Shingled," "shingling," or a "shingled layer," refers to an effect wherein a nonwoven web may be layered on itself owing to the overlap of fiber deposition on the forming surface as the jet of fibers coming from the die head oscillates back and forth over the moving collection wire resulting in the laying down of overlapping rows in the manner of shingles. Z-direction buckling may occur where the oscillations of fiber collection result in a Z-direction accumulation of the fibers which then fall towards the X-Y plane of the web resulting in the described shingling. The shingling and buckling thereof may be substantially irregular or random in nature but provide a higher loft and greater open space within the web.

DESCRIPTION OF PREFERRED EMBODIMENTS

Fig. 1 is a schematic diagram illustrating methods and apparatus of this invention for producing high loft, low density materials by producing crimpable bicomponent side by side substantially continuous fibers and causing them to crimp in an unrestrained environment.

Referring to Fig. 1, a schematic diagram is shown illustrating exemplary methods and apparatus of this invention for producing high loft, low density materials by producing crimpable bicomponent side by side substantially continuous fibers and causing them to crimp in an unrestrained environment. Two polymers A and B are spun with known thermoplastic fiber spinning apparatus 21 to form bicomponent side by side, or A/B, polymer masses 23. The polymer masses 23 are then traversed through a fiber draw unit (FDU) 25 to form fibers 24. According to one embodiment of the present invention, unlike the standard practice in the art, the FDU is not heated, but is left at ambient temperature (e.g., 65 °F). Thus, while the polymers will be recognized as having been heated to extrude the polymer masses, the actual fibers, as formed in the ambient temperature FDU, will be referred to and understood herein as having been deposited onto a forming surface without the addition of heat to the fibers before deposition. The fibers 24 are left in a substantially continuous state and are deposited on a moving forming wire or surface 27. Deposition of the fibers 24 is aided by an under-wire vacuum supplied by a negative air pressure unit, or below wire exhaust, 29.

The fibers 24 are then heated by traversal under one of a hot air knife (HAK) 31 or hot air diffuser 33, which are both shown in the figure but will be appreciated to be used in the alternative under normal circumstances. A conventional hot air knife includes a mandrel with a slot that blows a jet of hot air onto the nonwoven web surface. Such hot air knives are taught, for example, by U.S. Patent 5,707,468 to Arnold, et al. which is incorporated by reference in its entirety. The hot air diffuser 33 is an alternative which operates in a similar manner but with lower air velocity over a greater surface area and thus uses correspondingly lower air temperatures. The group, or layer, of fibers may receive an external skin melting or a small degree of nonfunctional bonding during this traversal through the first heating zone. "Nonfunctionally bonded" is a bonding sufficient only to hold the fibers in place for processing according to the method herein but so light as to not hold the fibers together were they to be manipulated manually. Such bonding may be incidental or eliminated altogether if desirable.

The fibers are then passed out of the first heating zone of the hot air knife 31 or hot air diffuser 33 to a second wire 35 where the fibers continue to cool and where the below wire exhaust 29 is removed so as to not disrupt crimping. As the fibers cool they will crimp in the z-direction, or out of the plane of the web, and form a high loft, low density nonwoven web 37. The web 37 is then transported to a through air bonding (TAB) unit 39 to set, or fix, the web at a desired degree of loft and density. Alternatively, the through air bonding (TAB) unit 39 can be zoned to provide a first heating zone in place of the hot air knife 31 or hot air diffuser 33, followed by a cooling zone, which is in turn followed by a second heating zone sufficient to fix the web. The fixed web 41 can then be collected on a winding roll 43 or the like for later use.

In accordance with one preferred embodiment of this invention, the substantially continuous fibers are bicomponent fibers. Webs of the present invention may contain a single denier structure (i.e., one fiber size) or a mixed denier structure (i.e., a plurality of fiber sizes). Particularly suitable polymers for forming the structural component of suitable bicomponent fibers include polypropylene and copolymers of polypropylene and ethylene, and particularly suitable polymers for the adhesive component of the bicomponent fibers includes polyethylene, more particularly linear low density polyethylene, and high density polyethylene. In addition, the adhesive component may contain additives for enhancing the crimpability

and/or lowering the bonding temperature of the fibers, as well as enhancing the abrasion resistance, strength and softness of the resulting webs. A particularly suitable bicomponent polyethylene/polypropylene fiber for processing according to the present invention is disclosed in the above-mentioned U.S. Patent Nos. 5,336,552 to Strack et al. and 5,382,400 to Pike et al. Webs made according to the present invention may further contain fibers having resins alternative to PP/PE, such as, without limitation: PET, Copoly-PP+3%PE, PLA, PTT, Nylon, PBT, etc. Fibers may be of various alternative shapes and symmetries including Pentaloble, Tri-T, Hollow, Ribbon, X, Y, H, and asymmetric cross sections.

Polymers useful in the manufacture of the system materials of the invention may further include thermoplastic polymers like polyolefins, polyesters and polyamides. Elastic polymers may also be used and include block copolymers such as polyurethanes, copolyether esters, polyamide polyether block copolymers, ethylene vinyl acetates (EVA), block copolymers having the general formula A-B-A' or A-B like copoly(styrene/ethylene-butylene), styrene-poly(ethylene-propylene)-styrene, styrene-poly(ethylene-butylene)-styrene, (polystyrene/poly(ethylene-butylene)/polystyrene, poly(styrene/ethylene-butylene/styrene) and the like.

Polyolefins using single site catalysts, sometimes referred to as metallocene catalysts, may also be used. Many polyolefins are available for fiber production, for example polyethylenes such as Dow Chemical's ASPUN7 6811A linear low density polyethylene, 2553 LLDPE and 25355 and 12350 high density polyethylene are such suitable polymers. The polyethylenes have melt flow rates, respectively, of about 26, 40, 25 and 12 at conditions of 190 °C and 2.16 Kg force. Fiber forming polypropylenes include Exxon Chemical Company's 3155 polypropylene and Montell Chemical Co.'s PF-304. Many other polyolefins are commercially available.

Biodegradable polymers are also available for fiber production and suitable polymers include polylactic acid (PLA) and a blend of BIONOLLE®, adipic acid and UNITHOX® (BAU). PLA is not a blend but a pure polymer like polypropylene. BAU represents a blend of BIONOLLE®, adipic acid, and UNITHOX® at different percentages. Typically, the blend for staple fiber is 44.1 percent BIONOLLE® 1020, 44.1 percent BIONOLLE® 3020, 9.8 percent adipic acid and 2 percent UNITHOX® 480, though spunbond BAU fibers typically use about 15 percent adipic acid. BIONOLLE® 1020 is polybutylene

succinate, BIONOLLE® 3020 is polybutylene succinate adipate copolymer, and UNITHOX® 480 is an ethoxylated alcohol. BIONOLLE® is a trademark of Showa Highpolymer Co. of Japan. UNITHOX® is a trademark of Baker Petrolite which is a subsidiary of Baker Hughes International. It should be noted that these biodegradable polymers are hydrophilic and so are preferably not used for the surface of the inventive intake system materials.

Per the above, the crimpable bicomponent fiber is heated by the HAK 31, hot air diffuser 33 or zoned TAB (not shown) in the first heating zone to a temperature where the polyethylene crystalline regions start to relax their oriented molecular chains and may begin melting. Typical air temperature used to induce crimp have ranged from about 110-260 °F. This temperature range represents temperatures of submelting degree, i.e., above the glass transition temperature (T_g) or softening point and below the melting point, which merely relax the molecular chain up through melting temperatures for the polymers. The heat of the air stream from the HAK 31 may be made higher due to the short dwell time of the fibers through its narrow heating zone. Further, when heat is applied to the oriented molecular chains of the fibers, the molecular chain mobility increases. Rather that being oriented, the chains prefer to relax in a random state. Therefore, the chains bend and fold causing additional shrinkage. Heat to the web may be applied by hot air, IR lamp, microwave or any other heat source that can heat the semi-crystalline regions of the polyethylene to relaxation.

Then the web passes through a cool zone that reduces the temperature of the polymer below its crystallization temperature. Since polyethylene is a semi-crystalline material, the polyethylene chains recrystallize upon cooling causing the polyethylene to shrink. This shrinkage induces a force on one side of the side-by-side fiber that allows it to crimp or coil if there are no other major forces restricting the fibers from moving freely in any direction. By using the cold FDU, the fibers are constructed so that they do not crimp in a tight helical fashion normal for fibers processed through a normal hot FDU. Instead, the fibers more loosely and randomly crimp, thereby imparting more z-direction loft to the fibers. Referencing Figs. 6, there are shown fibers produced from a normal hot FDU exhibiting a typically tight crimp. By comparison, Fig. 7 shows fibers produced from an ambient non-heated FDU exhibiting a much more relaxed macroscopic crimp conducive to a high loft web.

Factors that can affect the amount and type of crimp include the dwell time of the web under the heat of the first heating zone. Other factors affecting crimp can include

material properties such as fiber denier, polymer type, cross sectional shape and basis weight. Restricting the fibers with either a vacuum, blowing air, or bonding will also affect the amount of crimp and thus the loft, or bulk, desired to be achieved in the high loft, low density webs of the present invention. Therefore, as the fibers enter the cooling zone, no vacuum is applied to hold the fibers to the forming wire 27 or second wire 35. Blowing air is likewise controlled or eliminated in the cooling zone to the extent practical or desired.

According to one aspect of the present invention, the fibers may be deposited on the forming wire with a high degree of MD orientation as controlled by the amount of under-wire vacuum, the FDU pressure, and the forming height from the FDU to the wire surface. A high degree of MD orientation may be used to induce very high loft into the web, as further explained below. Further, dependent upon certain fiber and processing parameters, the air jet of the FDU will exhibit a natural frequency which may aid in the producing of certain morphological characteristics such as shingling effects into the loft of the web.

According to the exemplary embodiment of Fig. 1, wherein the fibers 24 are heated by air flow in the first heating zone and passed by the forming wire 27 to the second wire 35, several crimping mechanisms are believed to take place to aid in the lofting of the fibers, including, without being bound by theory:

the below-wire exhaust will cool the web by drawing surrounding air through it which prevents bonding but restricts formation of loft,

as the web is transferred out of the vacuum zone to the second wire, the vacuum force is removed and the unconstrained fibers are free to crimp,

mechanically, MD surface layer shrinkage of a highly MD oriented surface layer may cause the surface fibers to buckle,

mechanical shearing will be induced because the highly MD oriented surface shirring and bonds will leave subsurface fibers to continue shearing thereby creating loft by inducing shingling of the layers,

a mechanical buckling pattern may be produced at the natural frequency of the FDU jet which will cause the heated fibers to loft in the same frequency,

mechanical forces are created as fibers release from the forming wire 27 when leaving the vacuum area and then are briefly pulled back towards the vacuum unit 29, and

a triboelectric (frictional) static charge is built up on the web and causes the fibers to repel each other allowing further loft within the web.

Referencing Fig. 2, there is seen a photograph of a side view, or cross section, along the machine direction axis, of a high loft, low density nonwoven web 51 having z-direction components formed of crimped fibers according to the present invention. The web is formed with low machine direction orientation deposition of fibers onto the forming web and through air bonding to set the web. The crimping forms a random, heterogeneous z-direction orientation of the fibers. As can be seen, the spaces between the fibers are also randomly distributed and produce irregularly spaced openings. The through air bonding, which involves drawing heated air through the web to fix the web in its high loft state, results in some collapse of the initial loft of the web. The loft of the web is approximately 0.25 inches.

Referencing Fig. 3, there is seen a photograph of a side view, or cross section along the machine direction axis, of a very high loft, low density nonwoven web 53 having z-direction components formed of crimped fibers according to the present invention. The web is formed with low machine direction orientation deposition of fibers onto the forming web and static air bonding, where the web is undisturbed by drawn or blown air to set the web. The crimping forms a random, heterogeneous z-direction orientation of the fibers. As can be seen, the spaces between the fibers are also randomly distributed and produce irregularly spaced openings. The static air bonding, which does not involve drawing heated air through the web to fix the web in its high loft state, results in very little to no collapse of the initial loft of the web. The loft of the web is approximately 0.5625 inches.

Referencing Fig. 4, there is seen a photograph of a side view, or cross section along the machine direction axis, of a high loft, low density nonwoven web 55 having z-direction components including shingled layers, collectively 57, exhibiting z-direction buckling, as at 59, at a frequency substantially similar to the natural frequency of the FDU jet and formed of crimped fibers according to the present invention. The shingling and buckling thereof are substantially irregular or random in nature but provide a higher loft and greater open space within the web. The web is formed with high machine direction orientation deposition of fibers onto the forming web and through air bonding. The crimping forms a random, heterogeneous z-direction orientation of the fibers. The through air bonding, which

involves drawing heated air through the web to fix the web in its high loft state, results in some collapse of the initial loft of the web. The loft of the web is approximately 0.3125 inches.

Referencing Fig. 5, there is seen a photograph of a side view, or cross section along the machine direction axis, of a very high loft, low density nonwoven web having z-direction components including shingled layers 57 with z-direction buckling 59 at a frequency substantially similar to the natural frequency of the FDU jet and formed of crimped fibers according to the present invention. The shingling and buckling thereof are substantially irregular or random in nature but provide a higher loft and greater open space within the web. The web is formed with high machine direction orientation deposition of fibers onto the forming web and static air bonding to fix the web in the initially crimped configuration. The crimping forms a random, heterogeneous z-direction orientation of the fibers. The static air bonding, which does not involve drawing heated air through the web to fix the web in its high loft state, results in little to no collapse of the initial loft of the web. The loft of the web is approximately 1.0 inches.

A high loft low density web was made with 4.5 denier bicomponent spunbond fibers according to Strack et al. (supra) at about 0.14 inches loft, about 2.9 osy basis weight and 0.027 g/cc density, and tested for permeability, FIFE intake, flowback, filtration efficiency, and horizontal wicking. Results were generally superior in each category to a known high capillarity bonded carded web at 2.9 osy basis weight, 0.12 inches loft, and 0.032 g/cc density. Efficiency of the web of the present invention, as measured in a penetration test on TSI equipment, generally tested at over 55 percent or less. Specifically a web of the present invention tested at 3500 darcies permeability, 6 seconds FIFE intake, and 14 grams flowback as opposed to 2500 darcies, 10 seconds, 20 grams, respectively, for the bonded carded web.

Test Methods And Materials

Basis Weight: A circular sample of 3 inches (7.6 cm) diameter is cut and weighed using a balance. Weight is recorded in grams. The weight is divided by the sample area. Five samples are measured and averaged.

Material caliper (thickness): The caliper of a material is a measure of thickness and is measured at 0.05 psi (3.5 g/cm^2) with a STARRET®-type bulk tester, in units of millimeters. Samples are cut into 4 inch by 4 inch (10.2 cm by 10.2 cm) squares and five samples are tested and the results averaged.

Density: The density of the materials is calculated by dividing the weight per unit area of a sample in grams per square meter (gsm) by the material caliper in millimeters (mm). The caliper should be measured at 0.05 psi (3.5 g/cm^2). The result is multiplied by 0.001 to convert the value to grams per cubic centimeter (g/cc). A total of five samples would be evaluated and averaged for the density values.

Permeability: Permeability is obtained from a measurement of the resistance by the material to the flow of liquid. A liquid of known viscosity is forced through the material of a given thickness at a constant flow rate and the resistance to flow, measured as a pressure drop is monitored. Darcy's Law is used to determine permeability as follows:

Permeability = [flow rate x thickness x viscosity / pressure drop] [Equation 1]

where the units are:

permeability:	cm^2 or Darcy 1 Darcy = 9.87×10^{-9} cm^2
flow rate:	cm/sec
viscosity:	Pascal-sec
pressure drop:	Pascals

The apparatus consists of an arrangement wherein a piston within a cylinder pushes liquid through the sample to be measured. The sample is clamped between two aluminum cylinders with the cylinders oriented vertically. Both cylinders have an outside diameter of 3.5 inches (8.9 cm), an inside diameter of 2.5 inches (6.35 cm) and a length of about 6 inches (15.2 cm). The 3 inch diameter web sample is held in place by its outer edges and hence is completely contained within the apparatus. The bottom cylinder has a piston that is capable of moving vertically within the cylinder at a constant velocity and is connected to a pressure transducer that is capable of monitoring the pressure encountered by a column of liquid supported by the piston. The transducer is positioned to travel with the piston such that there is no additional pressure measured until the liquid column contacts the sample and is pushed through it. At this point, the additional pressure measured is due to the resistance of the material to liquid flow through it. The piston is moved by a slide assembly that is driven by a stepper motor. The test starts by moving the piston at a constant velocity until the liquid is pushed through the sample. The piston is then halted and the baseline pressure is noted. This corrects for sample buoyancy effects. The movement is then resumed for a time adequate to measure the new pressure. The difference between the two pressures is the pressure due to

the resistance of the material to liquid flow and is the pressure drop used in Equation (1). The velocity of the piston is the flow rate. Any liquid whose viscosity is known can be used, although a liquid that wets the material is preferred since this ensures that saturated flow is achieved. The measurements were carried out using a piston velocity of 20 cm/min, mineral oil (Peneteck Technical Mineral Oil manufactured by Penreco of Los Angeles, CA) of a viscosity of 6 centipoise.

Horizontal Wicking: This test measures how far liquid will move in a fabric when only one end of the fabric is immersed in the liquid and the fabric is horizontal. The fabric to be tested is prepared by cutting it into 1 inch (2.5 cm) by 8 inch (20.3 cm) strips in the machine direction. The sample is weighed and marked every 0.5 inch (13 mm) in the long dimension. The sample is placed on a 5 inch (12.7 cm) by 10 inch (25.4 cm) horizontal wire grid and slightly weighted so that it remains flat on the wire. A half inch of one end of the sample is submerged in a 0.5 inch deep by 0.5 inch wide by 5 inch long reservoir containing 10 ml of dyed 8.5 g/l saline solution. The end of the sample in the reservoir is held in place with a cylindrical glass stirring rod having a length of 1.5 inches (3.8 cm) and a diameter of 5/16 inches (7.9 mm) which also is submerged in the saline solution. The sample is allowed to rest with one end submerged in the reservoir for 20 minutes and is then carefully pulled horizontally out of the reservoir, cut at each 0.5 inch mark and each section weighed.

The dry sample weight is subtracted from the wet sample weight to arrive at fluid grams, and the 0.5 inch submerged in the reservoir is not considered. The total distance wicked is recorded along with the total grams of fluid wicked.

NaCl Efficiency: All filtration efficiency data are gathered from NaCl Efficiency testing. The NaCl Efficiency is a measure of the ability of a fabric or web to stop the passage of small particles through it. A higher efficiency is generally more desirable and indicates a greater ability to remove particles. NaCl efficiency is measured in percent according to the TSI Inc., Model 8130 Automated Filter Tester Operation Manual at a flow rate of 32 liters per minute using 0.1 micron (μm) sized NaCl particles and is reported as an average of 3 sample readings. The testing manual is available from TSI Inc., Particle Instrument Division, 500 Cardigan Rd, Shoreview, Minn. 55126, or one may visit www.tsi.com. This test also can yield a pressure differential across a fabric using the same particle size and airflow rate.

The Fluid Intake and Flowback Evaluation (FIFE) is performed to determine the intake potential of the composites. The FIFE entails insulting the structure by pouring a defined amount of 0.9 percent saline solution into a cylindrical column resting vertically on top of the structure and recording the time it takes for the fluid to be taken in by the structure. The sample to be tested is placed on a flat surface and the FIFE testing apparatus placed on top of the sample. The FIFE testing apparatus consisted of a rectangular, 35.3 by 20.3 cm, plexiglass piece upon which was centered a cylinder with an inside diameter of 30 mm. The flat piece had a 38 mm hole corresponding with the cylinder so that fluid could pass through it from the cylinder to the sample. The cylinder was centered 2 inches from top or front of the absorbent pad in the crotch of diaper. The FIFE testing apparatus weighed 517g.

Intake times are typically recorded in seconds. Samples were cut into 2.5 by 7 inch pledgets and were inserted into a STEP 4 HUGGIES ULTRATRIM (TM) commercially available diaper as a surge layer for the diaper. Samples were then insulted three times at 100 ml per insult with a wait of 15 minutes between the time the fluid was completely absorbed and the next insult.

After the third insult, the materials were placed on a vacuum box under 0.5 psi of pressure with a piece of blotter paper on top. The blotter paper was 110 lb. Verigood paper made by Fort James Corporation and was 3.5 by 12 inches (8.9 by 30.5 cm). The blotter paper was weighed before and after the test and the resulting differential reported as the flowback value as grams of fluid desorbed.

Formation Index (Uniformity) test:

The "Formation Index" is measured using a commercially available MK Formation Analyzer model 960, from MK Systems Inc. of Danvers, Massachusetts. Other digital image analysis systems with a minimum pixel density of 512 (horizontal) by 480 (vertical) and 8 bit resolution (giving 256 gray levels) might be used. Alternatively, an image analyzer suitable for the measurement of the Formation Index might be constructed from a "Pentium Class" personal computer containing a video frame grabber card such as the Flashpoint Intrique Pro (manufactured by Integral Technologies Inc. of Indianapolis, Indiana.) or equivalent frame grabbers from other vendors. Such personal computer-based systems are most effectively operated using specialized image analysis software available for the different frame grabber cards and construction of an adequate imaging system is considered to be within

the skill of the art. Whatever image analysis system is used, a video camera system is used for image input. Either image tube cameras or solid state cameras such as those utilizing Charge Coupled Devices may be used. The camera used to capture the present data was a Sony model XCES-50.

A 35 mm focal length lens is used with the camera. Any high quality lens may be used, such as Navitar 6.1 mm lens (from Navitar Inc. of Rochester, NY). The lens is attached to the camera through suitable adapters. Typically, the lens is operated with its aperture set to f/1.0.

The camera system views a web sample placed on the center of a light box having a diffuser plate. Whatever light box is used, it must have a uniform field of Lambertian (diffuse) illumination of adjustable intensity. The method of intensity adjustment must not change the color temperature of the illumination. One appropriate light box is the Fostec base light model AO-8927.

Specifically, 20 samples for the Formation Index testing are cut from a cross direction width strip of the nonwoven at locations throughout the strip. The samples are 3-inch by 3-inch squares (76 mm^2), with one side aligned with the machine direction of the test material. Each specimen is placed on the light box such that the side of the web to be measured for uniformity is facing up, away from the diffuser plate.

The specimen is set on the light box so that the center of the specimen is aligned with the center of the illumination field. All other natural or artificial room light is extinguished. The camera is adjusted so that its optical axis is perpendicular to the plane of the specimen and so that its video field is centered on the center of the specimen. The machine direction of the specimen is aligned with the vertical direction of the camera field. The camera is then positioned along its optical axis until its entire field of view contains exactly three inches of the specimen in the horizontal direction. The camera is focused so that the resulting picture contrast, measured as the standard deviation of the pixel array formed by digitization of the image, is maximized.

The M/K formation index is a measurement of uniformity of formation. The index value is the quotient of the number of pixels in the modal (most common) optical basis weight of pixel light divided by the total number of weight classes observed, divided by a factor of 100 for normalization. The optical basis weights for pixels of the MK Formation

Tester range from 0 (a hole in the sample) to 255 (almost no light transmission). The MK Formation Tester has a resolution of 64 different weight classes, each differing by about 1% in basis weight. Each weight class is made up of four optical basis weights. The higher the M/K formation index, the better the formation uniformity. Conversely, the lower the M/K formation index, the worse the formation uniformity.

Improvements in formation (or sheet uniformity) have been known to improve fabric strength and thus the performance of the fabric in their conversion or incorporation to absorbent articles. The results, however, are not to be used as a comparison between different grades (e.g., different color, basis weight, TiO_2 content, or the like which may affect light transmission/reflectance).

Examples

Selected for direct comparison with nonwovens according to the present invention is a nonwoven material of bicomponent spunbond fibers made according to Strack et al. (supra) available from Kimberly-Clark Corporation. Various descriptions of a bicomponent spunbond according to Strack et al. (supra) are taught in U.S. Patent Nos. 5,336,552 to Strack et al.; 5,382,400 or 5,418,045 to Pike et al., and 6,436,328 to DiPalma each of which is herein incorporated in its entirety by reference. A bicomponent spunbond according to Strack et al. (supra) is used as a basis to compare the articles and methods of the present invention since a bicomponent spunbond according to Strack et al. (supra) may generally comprise the same or similar components as the fibers of the present invention while being made by different techniques. For example, a bicomponent spunbond according to Strack et al. (supra) utilizes a hot FDU (e.g., 350 °F) to draw the fibers such that the fibers arrive at the collection wire already crimped. The fabrication techniques of a bicomponent spunbond according to Strack et al. (supra), hereinafter "hot FDU bicomponent spunbond," do not utilize the particular steps as taught herein to encourage the production and maintenance of maximum loft of the web. Further, the hot FDU will be recognized by the person having ordinary skill in the art as a limitation on fiber production which the present invention overcomes.

The hot FDU bicomponent spunbond is a nonwoven fabric and generally comprises extruded multicomponent polymeric strands including first and second polymeric components arranged in substantially distinctive zones across the cross-section of the

multicomponent strands and extending continuously along the length of the multicomponent strands. Exemplary embodiments are often taught as a 0.5 osy spunbond nonwoven, having fiber denier of approximately 2.0-2.5, and containing approximately 50% Polyethylene and 50% Polypropylene in a side-by-side configuration, with the web having a thermally point bonded structure.

A hot FDU bicomponent spunbond nonwoven fabric is generally made according to a process comprising the steps of melt spinning continuous multicomponent polymeric filaments in an A/B configuration comprising first and second polymeric components, the first and second components being arranged in substantially distinct zones across the cross-section of the multicomponent filaments and extending continuously along the length of the multicomponent filaments, with the second component constituting at least a portion of the peripheral surface of the multicomponent filaments. The first and second components are selected so that the multicomponent filaments are capable of developing latent helical crimp. The multicomponent filaments are drawn with a flow of air contacting the filaments and having a temperature sufficiently high to activate said latent helical crimp. Preferably, the multicomponent filaments are drawn with a fiber draw unit or aspirator by heated air at a temperature sufficient to heat the filaments to a temperature from about 110 °F to a maximum temperature less than the melting point of the lower melting component. However, it should be understood that the appropriate drawing air temperature to achieve the desired degree of crimping will depend on a number of factors including the type of polymers being used and the size of the filaments.

Preferably, the strands are continuous filaments which may be formed by spunbonding techniques. The second component of the strands may include a blend of a polyolefin and an ethylene alkyl acrylate copolymer. Bonds between the multicomponent strands may be formed by the application of heat.

Table 1 gives the values of each test code (i.e., fabric example type) used in comparing the uniformity of nonwovens of the present invention (hereinafter sometimes referred to as "cold FDU bicomponent spunbond") and comparable hot FDU bicomponent spunbond fabrics. Units and measures have been rounded in some instances for ease of presentation and reference may be had to the text below for more exact figures.

Table 1

example code	FDU temp	BASIS WT (in osy)	bulk (in inches)	denier	color	TiO_2 %
1	65 °F	6.0	0.50	3.3	white	2%
2	"	2.33	0.15	3.3	white	2%
3	"	2.27	0.13	3.3	white	2%
6	"	1.5	0.09	3.3	white	2%
7	"	1.5	0.09	2.3	white	2%
8	"	1.5	0.11	4.2	white	2%
9	"	1.5	0.10	3.2	white	0.5%
10	"	1.5	0.11	3.2	blue	-
11	"	1.2	0.06	3.2	white	2%
12	"	1.0	0.04	3.2	white	2%
13	"	0.77	0.03	3.2	white	2%
14	350 °F	6.0	0.35	3.2	white	2%
15	"	2.5	0.12	3.2	white	2%
16	"	2.25	0.12	3.2	white	2%
17	"	1.5	0.1	3.2	white	2%
18	"	1.2	0.08	3.2	white	2%
19	"	1.0	0.08	3.2	white	2%
20	"	0.75	0.07	3.2	white	2%

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Example 1

Example 1, was produced according to the present invention to a basis weight of 202 gsm (5.96 osy), with a bulk of 12.6 mm (0.5 inch) and density of 0.016 g/cc. The average denier was measured to be approximately 3.3 dpf (denier per fiber). The fibers were

side by side bicomponent, featuring polymer A of Dow 61800.41 polyethylene (PE) and polymer B of Exxon 3155 polypropylene (PP). A TiO_2 additive from the Standridge Color Corporation, of Social Circle, GA, tradenamed SCC-4837, was added to the polymer prior to extrusion at 2% by weight to provide white color and opacity to the web. The fibers were spun through a 96 hole per inch (hpi) spinpack, spinning in an A/B side by side (s/s) configuration, at a melt temperature of 410 °F.

Throughput was balanced in a 50/50 throughput ratio between the two polymers, with a total throughput of 0.7 grams per hole per minute (ghm). The quench air temperature was 55 °F. The fiber spin length was 48 inches. The fibers were drawn at 4.0 pounds/square inch/gram (psig) on bank 1, and 4.5 psig on bank 2, using ambient air of, e.g., approximately 65 °F.

The bottom of the fiber draw unit (FDU) was 12 inches above the forming wire, which was moving at 83 ft/min, as measured on the forming wire. The hot air knife (HAK) was set at 225 °F and 4.5 inches H_20 of pressure on bank 1, and 218 °F and 4.0 inches H_20 on bank 2, at a height of 5.0 inches above the forming wire. The below wire exhaust under the FDU was set to vacuum of approximately 1.7 inches H_20 in bank 1, and 3.9 inches H_20 in bank 2. The web was bonded at approximately 262-269 °F in a through air bonder (TAB).

Example 2

Example 2, was produced according to the present invention to a basis weight of 79 gsm (2.33 osy), with a bulk of 3.8 mm (0.15 inches) and density of 0.021 g/cc. The average denier was measured to be approximately 3.3 dpf. Polymers and additives were the same as stated for Example 1.

Fiber and web formation conditions were the same as for Example 1 except the forming wire was moving at 220 ft/min, as measured on the forming wire. The HAK was set at 250 °F and 5.0 inches H_20 of pressure on bank 1, and 240 °F and 3.5 inches H_20 on bank 2, at a height of 5.0 inches above the forming wire. The below wire exhaust under the fiber draw unit was set to vacuum of approximately 1.7 inches H_20 in bank 1, and 3.8 inches H_20 in bank 2.

Example 3

Example 3, was produced according to the present invention to a basis weight

of 77 gsm (2.27 osy), with a bulk of 3.3 mm (0.13 inch) and density of 0.023 g/cc. The average denier was measured to be approximately 3.3 dpf.

Fiber and web formation conditions were the same as for Example 1 except the forming wire was moving at 229 ft/min, as measured on the forming wire. The HAK was set at 250 °F and 5.0 inches H_20 of pressure on bank 1, and 240 °F and 3.5 inches H_20 on bank 2, at a height of 5.0 inches above the forming wire. The below wire exhaust under the fiber draw unit was set to vacuum of approximately 1.6 inches H_20 in bank 1, and 3.8 inches H_20 in bank 2. The web was bonded at approximately 262-269 °F in a through air bonder.

Example 6

Example 6, was produced according to the present invention to a basis weight of 52 gsm (1.53 osy), with a bulk of 2.2 mm (0.087 inches) and density of 0.024 g/cc. The average denier was measured to be approximately 3.3 dpf.

Fiber and web formation conditions were the same as for Example 1 except the fibers were drawn at 4.2 psig on bank 1, and 4.2 psig on bank 2. The forming wire was moving at 345 ft/min, as measured on the forming wire. The HAK was set at 253 °F and 3.5 inches H_20 of pressure on bank 1, and 250 °F and 3.7 inches H_20 on bank 2, at a height of 1.0 inches above the forming wire. The below wire exhaust under the fiber draw unit was set to vacuum of approximately 1.6 inches H_20 in bank 1, and 5.2 inches H_20 in bank 2. The web was bonded at approximately 264-265 ° F in a through air bonder.

Example 7

Example 7, was produced according to the present invention to a basis weight of 52 gsm (1.53 osy), with a bulk of 2.3 mm (0.091 inches) and density of 0.023 g/cc. The average denier was measured to be approximately 2.3 dpf.

Fiber and web formation conditions were the same as for Example 1 except that the fibers were drawn at 4.8 psig on bank 1, and 4.8 psig on bank 2. The forming wire was moving at 345 ft/min, as measured on the forming wire. The HAK was set at 253 °F and 3.5 inches H_20 of pressure on bank 1, and 250 °F and 3.7 inches H_20 on bank 2, at a height of 1.0 inches above the forming wire. The below wire exhaust under the fiber draw unit was set to vacuum of approximately 1.6 inches H_20 in bank 1, and 5.2 inches H_20 in bank 2. The web was bonded at approximately 264-265 °F in a through air bonder.

Example 8

Example 8 was produced according to the present invention to a basis weight of 51 gsm (1.50 osy), with a bulk of 2.8 mm (0.11 inches) and density of 0.018 g/cc. The average denier was measured to be approximately 4.2 dpf.

Fiber and web formation conditions were the same as for Example 1 except that the fibers were drawn at 3.5 psig on bank 1, and 3.5 psig on bank 2. The forming wire, was moving at 345 ft/min, as measured on the forming wire. The HAK was set at 253 °F and 3.5 inches H_20 of pressure on bank 1, and 250°F and 3.7 inches H_20 on bank 2, at a height of 1.0 inches above the forming wire. The below wire exhaust under the fiber draw unit was set to vacuum of approximately 1.6 inches H_20 in bank 1, and 5.3 inches H_20 in bank 2. The web was bonded at approximately 264-265°F in a through air bonder.

Example 9

Example 9 was produced according to the present invention to a basis weight of 51 gsm (1.50 osy), with a bulk of 2.5 mm (0.10 inches) and density of 0.021 g/cc. The average denier was measured to be approximately 3.2 dpf.

Fiber and web formation conditions were the same as for Example 1 except that the fibers were drawn at 4.2 psig on bank 1, and 4.2 psig on bank 2, using ambient air of approximately 65 °F. The forming wire was moving at 345 ft/min, as measured on the forming wire. The HAK was set at 253 °F and 3.5 inches H_20 of pressure on bank 1, and 250 °F and 3.7 inches H_20 on bank 2, at a height of 1.0 inches above the forming wire. The below wire exhaust under the fiber draw unit was set to vacuum of approximately 1.6 inches H_20 in bank 1, and 5.3 inches H_20 in bank 2. The web was bonded at approximately 265 °F in a through air bonder.

Example 10

Example 10 was produced according to the present invention to a basis weight of 52 gsm (1.53 osy), with a bulk of 2.8 mm (0.11 inches) and density of 0.018 g/cc. The average denier was measured to be approximately 3.2 dpf. An additive tradenamed SCC-3185, from the Standridge Color Corporation, was added to the polymer prior to extrusion at 3.8% by weight to provide blue color to the web.

Fiber and web formation conditions were the same as for Example 1 except that the fibers were drawn at 4.2 psig on bank 1, and 4.2 psig on bank 2, using ambient air of approximately 65 °F. The forming wire was moving at 345 ft/min, as measured on the forming

wire. The HAK was set at 253 °F and 3.5 inches H_20 of pressure on bank 1, and 250 °F and 3.7 inches H_20 on bank 2, at a height of 1.0 inches above the forming wire. The below wire exhaust under the fiber draw unit was set to vacuum of approximately 1.6 inches H_20 in bank 1, and 5.2 inches H_20 in bank 2. The web was bonded at approximately 264-265 °F in a through air bonder.

Example 11

Example 11, was produced according to the present invention to a basis weight of 41 gsm (1.21 osy), with a bulk of 1.6 mm (0.063 inches) and density of 0.026 g/cc. The average denier was measured to be approximately 3.2 dpf.

Fiber and web formation conditions were the same as for Example 6 except that the forming wire was moving at 430 ft/min, as measured on the forming wire. The HAK was set at 260 °F and 5.0 inches H_20 of pressure on bank 1, and 265 °F and 3.5 inches H_20 on bank 2, at a height of 1.0 inches above the forming wire. The below wire exhaust under the fiber draw unit was set to vacuum of approximately 2.0 inches H_20 in bank 1, and 4.5 inches H_20 in bank 2. The web was bonded at approximately 261-274 °F in a through air bonder.

Example 12

Example 12, was produced according to the present invention to a basis weight of 35 gsm (1.03 osy), with a bulk of 1.1 mm (0.043 inches) and density of 0.032 g/cc. The average denier was measured to be approximately 3.2 dpf.

Fiber and web formation conditions were the same as for Example 6 except that the forming wire was moving at 516 ft/min, as measured on the forming wire. The HAK was set at 270 °F and 8.0 inches H_20 of pressure on bank 1, and 270 °F and 5.0 inches H_20 on bank 2, at a height of 1.0 inches above the forming wire. The below wire exhaust under the fiber draw unit was set to vacuum of approximately 2.0 inches H_20 in bank 1, and 4.5 inches H_20 in bank 2. The web was bonded at approximately 265-277 °F in a through air bonder.

Example 13

Example 13, was produced according to the present invention to a basis weight of 26 gsm (0.77 osy), with a bulk of 0.7 mm (0.028 inches) and density of 0.039 g/cc. The average denier was measured to be approximately 3.2 dpf.

Fiber and web formation conditions were the same as for Example 6 except that the forming wire was moving at 688 ft/min, as measured on the forming wire. The HAK

was set at 296 °F and 9.0 inches H_20 of pressure on bank 1, and 287 °F and 12.0 inches H_20 on bank 2, at a height of 1.0 inches above the forming wire. The below wire exhaust under the fiber draw unit was set to vacuum of approximately 2.5 inches H_20 in bank 1, and 4.4 inches H_20 in bank 2. The web was bonded at approximately 265-277 °F in a through air bonder.

Example 14 (hot FDU bicomponent spunbond)

Example 14 was produced according to the above-described hot FDU bicomponent spunbond technology of Strack et al. (supra) to a basis weight of 199 gsm (5.87 osy), with a bulk of 8.9 mm (0.35 inches) and density of 0.022 g/cc. The average denier was measured to be approximately 3.3 dpf.

Fibers were bicomponent, featuring polymer A of Dow 61800.41 PE and polymer B of Exxon 3155 PP. An additive tradenamed SCC-4837 from the Standridge Color Corporation, was added to the polymer prior to extrusion at 2.0% by weight to provide white color and opacity to the web. The fibers were spun through a 96 hpi pack, spinning in a side by side (s/s) configuration, at a melt temperature of 410 °F.

Throughput was balanced in a 50/50 throughput ratio between the two polymers, with a total throughput of 0.7 ghm. The quench air temperature was 56 °F. The fiber spin length was 48 inches. The fibers were drawn at 4.2 psig on bank 1, and 4.2 psig on bank 2, using heated air of approximately 350 °F. The bottom of the FDU was 12 inches above the forming wire, which was moving at 86 ft/min, as measured on the forming wire. The HAK was set at 201 °F and 3.5 inches H_20 of pressure on bank 1, and 206 °F and 3.7 inches H_20 on bank 2, at a height of 1.0 inches above the forming wire. The below wire exhaust under the fiber draw unit was set to vacuum of approximately 5.5 inches H_20 in bank 1, and 6.5 inches H_20 in bank 2. The web was bonded at approximately 254-262 °F in a through air bonder.

Example 15 (hot FDU bicomponent spunbond)

Example 15 was produced according to the above-described hot FDU bicomponent spunbond technology to a basis weight of 86 gsm (2.54 osy), with a bulk of 3.0 mm (0.12 inches) and density of 0.028 g/cc. The average denier was measured to be approximately 3.3 dpf.

Fiber and web formation conditions were the same as for Example 14 except that the forming wire was moving at 200 ft/min, as measured on the forming wire. The HAK

was set at 248 °F and 3.5 inches H_20 of pressure on bank 1, and 255 °F and 3.7 inches H_20 on bank 2, at a height of 1.0 inches above the forming wire. The below wire exhaust under the fiber draw unit was set to vacuum of approximately 5.4 inches H_20 in bank 1, and 6.3 inches H_20 in bank 2. The web was bonded at approximately 254-261 °F in a through air bonder.

Example 16 (hot FDU bicomponent spunbond)

Example 16 was produced according to the above-described hot FDU bicomponent spunbond technology to a basis weight of 77 gsm (2.27 osy), with a bulk of 3.1 mm (0.12 inches) and density of 0.024 g/cc. The average denier was measured to be approximately 3.3 dpf.

Fiber and web formation conditions were the same as for Example 14 except that the forming wire was moving at 226 ft/min, as measured on the forming wire. The HAK was set at 248 °F and 3.5 inches H_20 of pressure on bank 1, and 255 °F and 3.7 inches H_20 on bank 2, at a height of 1.0 inches above the forming wire. The below wire exhaust under the fiber draw unit was set to vacuum of approximately 5.4 inches H_20 in bank 1, and 6.3 inches H_20 in bank 2. The web was bonded at approximately 254-262 °F in a through air bonder.

Example 17 (hot FDU bicomponent spunbond)

This example was produced according to the above-described hot FDU bicomponent spunbond technology to a basis weight of 51 gsm (1.50 osy), with a bulk of 2.6 mm (0.10 inches) and density of 0.020 g/cc. The average denier was measured to be approximately 3.2 dpf.

Fiber and web formation conditions were the same as for Example 14 except that the forming wire was moving at 340 ft/min, as measured on the forming wire. The HAK was set at 264 °F and 3.5 inches H_20 of pressure on bank 1, and 259 °F and 3.7 inches H_20 on bank 2, at a height of 1.0 inches above the forming wire. The below wire exhaust under the fiber draw unit was set to vacuum of approximately 5.3 inches H_20 in bank 1, and 6.2 inches H_20 in bank 2. The web was bonded at approximately 255-262 °F in a through air bonder.

Example 18 (hot FDU bicomponent spunbond)

Example 18, was produced according to the prior art as detailed for hot FDU bicomponent spunbond fiber and fabric to a basis weight of 41 gsm (1.21 osy) , with a bulk of 2.0 mm (0.079 inches) and density of 0.021 g/cc. The average denier was measured to be approximately 3.2 dpf.

Fiber and web formation conditions were the same as for Example 14 except that the forming wire was moving at 420 ft/min, as measured on the forming wire. The HAK was set at 268 °F and 3.5 inches H_20 of pressure on bank 1, and 265 °F and 3.7 inches H_20 on bank 2, at a height of 1.0 inches above the forming wire. The below wire exhaust under the fiber draw unit was set to vacuum of approximately 5.3 inches H_20 in bank 1, and 6.2 inches H_20 in bank 2. The web was bonded at approximately 255-262 °F in a through air bonder.

Example 19 (hot FDU bicomponent spunbond)

Example 19, was produced according to the prior art as detailed for hot FDU bicomponent spunbond fiber and fabric to a basis weight of 34 gsm (1.00 osy), with a bulk of 2.0 mm (0.079 inches) and density of 0.017 g/cc. The average denier was measured to be approximately 3.2 dpf.

Fiber and web formation conditions were the same as for Example 14 except that the forming wire was moving at 500 ft/min, as measured on the forming wire. The HAK was set at 277 °F and 3.5 inches H_20 of pressure on bank 1, and 270 °F and 3.7 inches H_20 on bank 2, at a height of 1.0 inches above the forming wire. The below wire exhaust under the fiber draw unit was set to vacuum of approximately 5.3 inches H_20 in bank 1, and 6.2 inches H_20 in bank 2. The web was bonded at approximately 255-267 °F in a through air bonder.

Example 20 (hot FDU bicomponent spunbond)

Example 20, was produced according to the prior art as detailed for hot FDU bicomponent spunbond fiber and fabric to a basis weight of 26 gsm (0.77 osy), with a bulk of 1.8 mm (0.071 inches) and density of 0.015 g/cc. The average denier was measured to be approximately 3.2 dpf.

Fiber and web formation conditions were the same as for Example 14 except that the forming wire was moving at 667 ft/min, as measured on the forming wire. The HAK was set at 300 °F and 3.5 inches H_20 of pressure on bank 1, and 295 °F and 3.7 inches H_20 on bank 2, at a height of 1.0 inches above the forming wire. The below wire exhaust under the fiber draw unit was set to vacuum of approximately 3.2 inches H_20 in bank 1, and 6.2 inches H_20 in bank 2. The web was bonded at approximately 255-266 °F in a through air bonder.

Tables 2 and 3 detail the M/K formation index testing results. Table 2 gives the raw data for each of the Cold FDU example codes of Table 1 as well as the average formation index value and the standard deviation between the samples. Table 3 provides a

comparison between the comparable Cold FDU samples and Hot FDU samples of the Table 1. While the data is set forth for webs with basis weights between about 0.75 osy and about 6.0 osy, the inventors believe that the trends witnessed in the data will apply to those basis weights in the range of about 0.33 osy to about 12.0 osy. In terms of bulk, while the data is set forth for webs with bulk between about 0.03 inches and 0.50 inches, the inventors believe that the trends witnessed in the data will apply to any comparison of webs with bulk of between about 0.02 to about 1.5 inches. Further, while the data is set forth for webs with fibers having between 2.3 and 4.2 dpf, the inventors believe that the trends witnessed in the data will apply to any comparison of webs with like fiber deniers and especially to those fiber deniers in the range of between about 0.1 dpf to about 9.0 dpf. Also, while the data is set forth for various fiber colors, and especially white fiber colors having between 0.5 and 2.0 percentage of TiO_2, the inventors believe that the trends witnessed in the data will apply to any comparison of webs between like fiber colors and especially to those white fiber colors having in the range of between about 0.1 to about 6.0 percent addition of TiO_2.

It will be noted that generally the Cold FDU samples of the present invention provide a significant increase in the formation index value, thereby indicating an improved uniformity of fabric over the comparable fabrics made according to the methods of the prior art. The person having ordinary skill in the art will note that the percentage of difference between the top side formation index and the bottom side formation index is much lower for the webs of the present invention than that of the comparison webs of the known art, thus indicating more uniformity between the major surfaces of the web. Applicants have calculated that the percentage of difference between the surfaces, defined as: highest formation index minus lowest formation index/ highest formation index, affords a significantly better uniformity between the major surfaces, i.e. those in the X-Y plane, for webs of the present invention. Without being bound by theory, this may be due to the fact that the fibers of the present invention are deposited on the forming surface, i.e. "wire," while still in an uncrimped state, while the fibers of the comparison webs of the known art are deposited on the wire while crimped. It is believed that the fibers of the present invention therefore lay more uniformly upon deposition, thereby leading to more uniformity between the top and the bottom, or wire side, web surfaces even after the fibers undergo post-deposition crimping. Such webs of the present invention may have increased utility where both sides of the web are visible during

later utilization and may further offer benefits in terms of less reliance on presenting the most uniform side of the web during later utilization. It will further be noted that in certain instances, especially in higher bulk or higher basis weight fabrics, that significant differences in the formation index values are not apparent as to one or more sides of the nonwoven. Without being bound by theory, it is speculated that the lack of significant differences in the formation indices may be due at least in part to the nature of light transmission within the subject fabrics which could effect overall M/K test results.

TABLE 2

	code 1 - 6.0osy cold FDU		code 2 - 2.5osy cold FDU		code 3 - 2.25osy cold FDU		code 6 - 1.5osy cold FDU		code 7 - 1.5osy cold FDU, 2.5dpf		code 8 - 1.5osy cold FDU, 4.2dpf		code 9 - 1.5osy cold FDU, .5% TIO2		code 10 - 1.5osy cold FDU, Blue		code 11 - 1.2osy cold FDU		code 12 - 1.0osy cold FDU		code 13 - 0.75osy cold FDU	
M/K Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index
	Top side	Bottom Side	Top side	Bottom Side	Top side	Bottom Side	Top side	Bottom Side	Top side	Bottom Side	Top side	Bottom Side	Top side	Bottom Side	Top side	Bottom Side	Top side	Bottom Side	Top side	Bottom Side	Top side	Bottom Side
Rep																						
1	35.0	27.0	28.6	31.1	30.3	34.8	54.3	59.6	38	43.5	29.8	29.4	49.4	54.6	30.1	33.9	46.5	49.7	55.8	59.6	67.7	58.3
2	25.9	46.1	33.3	36.2	36.6	30.6	49.5	54.3	43.1	47.3	40.2	34.5	77.7	62.5	39.4	36.9	54.3	61.9	63	76.2	77.3	75.9
3	36.6	36.1	31.3	38.9	38.9	33.2	40.1	65.1	57.4	50.7	41.7	42.8	67.3	75.5	35.4	29.8	42.6	60.2	44.2	52.8	89.3	74.5
4	39.5	25.2	37.3	28.7	33	38.4	32.4	45.8	47	55.4	25.6	44.4	51.9	77.9	29.2	32.8	46.6	30.1	60.8	69.7	73.5	69.8
5	49.9	46.9	43.3	43.3	24.6	34.4	61.9	49.3	30.7	41	32.9	44.1	82	74.4	40.1	33.6	52.8	50.5	65.7	70.5	78.7	72.6
6	36.8	33.9	32.6	31.8	35.6	38.2	43.2	47.9	37.5	45.5	32.2	29.5	64.7	69.8	26.9	39.6	54.7	43.9	57.9	60.4	73.4	73.2
7	27.6	17.9	31.9	39.2	29.1	39.3	34.2	48.3	53.9	50	33.7	40	58.9	65.4	23.6	34.3	44.3	50.9	66.6	66.1	68.5	63.4
8	31.2	21.4	31.4	32.4	33.8	25.4	54.5	59.6	45.6	45.3	29.5	43.8	64.3	62.2	30.6	39.9	43	45.9	54.5	70.4	51.1	73.2
9	24.5	43.0	29.9	35.2	40.9	34.5	45.7	51.6	43.6	54.8	29.2	42	70.7	52.4	35.4	38.3	63.5	55.2	64.2	62.6	81.1	89.2
10	28.8	34.8	42	39.9	44.2	42	51.1	41.1	39.1	51	33.8	34.9	55.9	70.1	33.6	38	59	48.9	49.1	64.5	85.1	70.6
11	47.4	33.6	33.9	25.4	27	29.3	44.5	49.2	48.2	44.3	33.3	41.6	70.6	58.2	37.8	30.8	45.1	49.7	60.9	67.7	64.4	65.9
12	34.9	26.1	28.2	36.4	41.6	34.1	43.5	36.5	45.5	49.1	29.5	45.5	77.5	69.7	31.1	35.8	53	49.6	57.2	69.3	88.6	75.8
13	30.1	29.3	36.7	40.7	38.8	34.1	53.8	52.9	39.1	55.8	38.4	39.8	63.3	66.9	30.3	37.1	48.4	38.8	49.1	57	68.1	70.5
14	30.2	25.2	29.6	34.8	36	32	52	52.6	58.2	49	40.7	46.6	72.2	69.5	34.5	24.2	49.2	58	73.1	75.5	63.3	67.9
15	28.4	41.2	29.2	41.7	39.8	41.1	50.3	40.8	46.7	57.8	36.5	30	63.3	69.7	30.2	28.5	45.5	44.4	65.1	60.5	87.7	79
16	45.0	28.2	32.7	34.3	33.3	44.8	52.8	43	55.2	50.3	39.2	40.2	62.2	61.2	29.9	29.4	58.9	41.9	65	67.4	89.8	83.1
17	23.7	28.8	35.4	30.9	40.7	40	52.4	43.2	42.2	41.9	35.4	30	59.5	61.9	36.8	35.7	49.7	53	64.1	62	65.4	70.4
18	39.8	33.1	36.7	32.1	32.4	26.6	46.6	57.6	39.2	47.8	33.9	38.9	58.8	78.5	38.2	44.7	61.4	56.2	54.6	51.1	71.8	72.5
19	30.8	25.4	41.2	45.1	29.3	35.7	41.3	59.3	48	40.7	44	50.5	82.3	59	26.6	35.7	57.9	61	71.5	74.9	70.7	69.4
20	26.9	39.6	36.6	45.5	46.2	36.8	41	40.1	60.5	40.9	37.1	44.1	56.4	68.7	34.3	39.8	54.4	54.1	51.2	49.8	63.5	61.9
Average	33.65	32.14	34.09	36.18	35.605	35.265	47.255	49.89	45.935	48.105	34.83	39.63	65.445	66.405	32.7	34.94	51.54	50.195	59.68	64.4	73.95	71.855
Std. Dev.	7.6	8.1	4.478	5.529	5.835	5.021	7.349	7.807	7.905	5.248	4.866	6.255	9.5	7.349	4.55	4.786	6.373	7.935	7.704	7.825	10.582	7.045

TABLE 3

	code 1 - 6.0osy cold FDU		code 2 - 2.5osy cold FDU		code 3 - 2.25osy cold FDU		code 6 - 1.5osy cold FDU		code 11 - 1.2osy cold FDU		code 12 - 1.0osy cold FDU		code 13 - 0.75osy cold FDU	
M/K Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index
	Top side	Bottom Side	Top side	Bottom Side	Top side	Bottom Side	Top side	Bottom Side	Top side	Bottom Side	Top side	Bottom Side	Top side	Bottom Side
Rep														
1	35.0	27.0	28.6	31.1	30.3	34.8	54.3	59.6	46.5	49.7	55.8	59.6	67.7	58.3
2	25.9	46.1	33.3	36.2	36.6	30.6	49.5	54.3	54.3	61.9	63	76.2	77.3	75.9
3	36.6	36.1	31.3	38.9	38.9	33.2	40.1	65.1	42.6	60.2	44.2	52.8	89.3	74.5
4	39.5	25.2	37.3	28.7	33	38.4	32.4	45.8	46.6	30.1	60.8	69.7	73.5	69.8
5	49.9	46.9	43.3	43.3	24.6	34.4	61.9	49.3	52.8	50.5	65.7	70.5	78.7	72.6
6	36.8	33.9	32.6	31.8	35.6	38.2	43.2	47.9	54.7	43.9	57.9	60.4	73.4	73.2
7	27.6	17.9	31.9	39.2	29.1	39.3	34.2	48.3	44.3	50.9	66.6	66.1	68.5	63.4
8	31.2	21.4	31.4	32.4	33.8	25.4	54.5	59.6	43	45.9	54.5	70.4	51.1	73.2
9	24.5	43.0	29.9	35.2	40.9	34.5	45.7	51.6	63.5	55.2	64.2	62.6	81.1	89.2
10	28.8	34.8	42	39.9	44.2	42	51.1	41.1	59	48.9	49.1	64.5	85.1	70.6
11	47.4	33.6	33.9	25.4	27	29.3	44.5	49.2	45.1	49.7	60.9	67.7	64.4	65.9
12	34.9	26.1	28.2	36.4	41.6	34.1	43.5	36.5	53	49.6	57.2	69.3	88.6	75.8
13	30.1	29.3	36.7	40.7	38.8	34.1	53.8	52.9	48.4	38.8	49.1	57	68.1	70.5
14	30.2	25.2	29.6	34.8	36	32	52	52.6	49.2	58	73.1	75.5	63.3	67.9
15	28.4	41.2	29.2	41.7	39.8	41.1	50.3	40.8	45.5	44.4	65.1	60.5	87.7	79
16	45.0	28.2	32.7	34.3	33.3	44.8	52.8	43	58.9	41.9	65	67.4	89.8	83.1
17	23.7	28.8	35.4	30.9	40.7	40	52.4	43.2	49.7	53	64.1	62	65.4	70.4
18	39.8	33.1	36.7	32.1	32.4	26.6	46.6	57.6	61.4	56.2	54.6	51.1	71.8	72.5
19	30.8	25.4	41.2	45.1	29.3	35.7	41.3	59.3	57.9	61	71.5	74.9	70.7	69.4
20	26.9	39.6	36.6	45.5	46.2	36.8	41	40.1	54.4	54.1	51.2	49.8	63.5	61.9
Average	33.65	32.14	34.09	36.18	35.605	35.265	47.255	49.89	51.54	50.195	59.68	64.4	73.95	71.855
Std. Dev.	7.6	8.1	4.478	5.529	5.835	5.021	7.349	7.807	6.373	7.935	7.704	7.825	10.582	7.045

	code 14 - 6.0osy hot FDU		code 15 - 2.5osy hot FDU		code 16 - 2.25osy hot FDU		code 17 - 1.5osy hot FDU		code 18 - 1.2osy hot FDU		code 19 - 1.0osy hot FDU		code 20 - 0.75osy hot FDU	
M/K Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index	Formation Index
	Top side	Bottom Side	Top side	Bottom Side	Top side	Bottom Side	Top side	Bottom Side	Top side	Bottom Side	Top side	Bottom Side	Top side	Bottom Side
Rep														
1	20.5	19.8	30.9	31.8	33.6	31.3	20	40.5	26.1	32.8	26	41.5	23.9	37
2	12.2	40.3	28.3	26.1	33.1	40.6	25.5	35.9	30.5	52.7	41.1	39.7	36.7	41.4
3	18	48.4	31.3	35.7	36.3	30.9	32	40.3	39	42.5	35.4	46.5	41.8	41.1
4	18.8	20.7	31.7	44.7	28.9	39.3	30.9	38.8	32.8	40.7	33.8	38.9	37.8	44.4
5	23.4	44.9	35.6	43.1	36.1	28.9	37.2	33.7	35.5	42.8	35.4	40.2	40.1	45.3
6	21.1	44.1	35.5	36.2	31.3	37.2	25.7	37	28.1	30.5	31.8	39.2	30	37.9
7	21.7	29.2	31.1	39.5	30.7	37.4	27.5	26.9	24.1	28.5	27.9	37.8	30.5	43.5
8	16.3	26.7	34.1	35.2	22	42.1	22.7	27.7	31.9	32.2	29.7	31.7	29.6	43.7
9	21.1	16.2	25.5	33.8	32.8	36.3	26.8	39.8	36.7	33.6	39.8	45.3	33.6	46.8
10	20.2	15.7	34.3	36.6	32.8	31.4	40.5	46	32.8	32.7	36	43.4	49	53
11	20.1	9.3	33.1	32.7	38.9	38.7	31.3	33.5	27.2	37.6	35.5	44.4	41.6	48.1
12	17.5	41.3	36.1	43	33.2	37.1	28	40.8	33.2	32	37.5	46.2	32.7	47.1
13	14.2	31.9	34.5	44.6	30.5	31.7	22.3	30.8	23.1	44.3	31.6	22.6	36.4	48
14	10.6	34.3	33.1	38.9	17.3	36.5	23.6	31.1	25.9	25.4	32.3	32.6	44	40.8
15	22.8	33.9	29	35	30.3	24.7	24.1	26.1	28.8	35.7	36.5	36.9	38.6	36.2
16	25.8	38.3	27.3	35.7	22.5	33.7	30.1	33.5	41.4	38.3	32.9	37.8	47.1	44.9
17	23.5	25.5	35.2	36.2	34.2	36.8	28.2	39.9	33.5	50.2	41.6	54.4	44.3	46.8
18	14.4	40.5	38.6	37.1	20.9	33.6	34.4	32.1	34.6	41.1	45.7	33.1	42.4	50.2
19	20.9	39.2	31.9	42.3	32.1	37.7	36.8	39.6	24.7	40.7	36.9	29.2	33.6	43.9
20	18.3	31.8	23.5	33.6	27.9	34.7	26.9	33.4	31.4	28.6	25.2	38.1	38.3	35.1
Average	19.07	31.6	32.03	37.09	30.27	35.03	28.725	35.37	31.065	37.145	34.63	38.975	37.6	43.76
Std. Dev.	3.953	10.983	3.812	4.737	5.609	4.26	5.439	5.36	5.047	7.258	5.23	7.048	6.443	4.763

The high loft, low density webs according to the present invention are believed to provide excellent fluid handling characteristics such as may be desirable for filtration media, and fluid distribution or absorption layers of absorbent products and may further suitable for a variety of insulation type fabrics. The person having ordinary skill in the art will recognize that many characteristics of the web may be controlled to produce a variety of high loft, low density morphologies, including, but not limited to, fiber denier, deposition rates, heating and cooling rates, and the amount of forces applied to impede the crimping processes as set forth herein.

While in the foregoing specification this invention has been described in relation to certain preferred embodiments thereof, and many details have been set forth for purpose of illustration, it will be apparent to those skilled in the art that the invention is susceptible to additional embodiments and that certain of the details described herein can be varied considerably without departing from the basic principles of the invention.